Impact of ESW on Climates of Terrestrial-Type Exoplanets

PI: Michal Way(GISS)
Science PI: Vlad Airapetian (671/ AU) Co-I: Guillaume Gronoff (SSAI) Collaborator: Eric Wolf (UC Boulder)

Duration of Award: FY18 (6m) – FY20

Main objectives

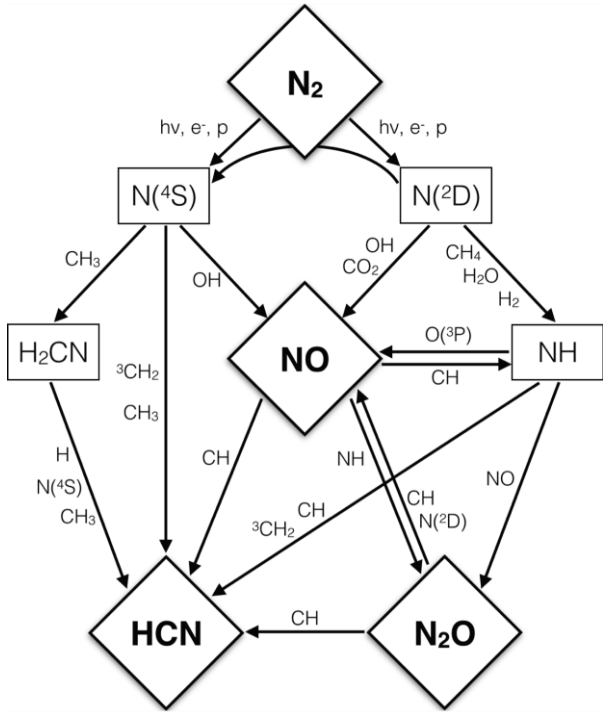
****Model atmospheric chemistry of terrestrial planets modified by activity***

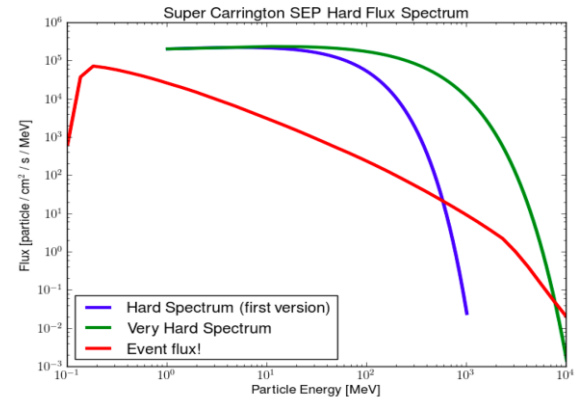
****Apply ROCKE3D to model climates of exoplanetary atmospheres***

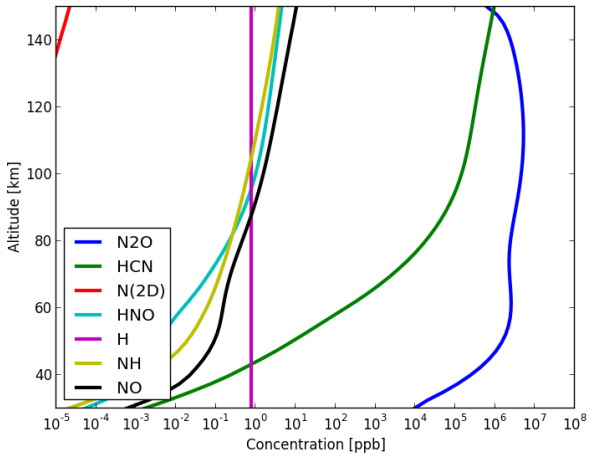
****Model reflectance and transmission spectra of Mars to Super Earth-size exoplanets***

****Explore diverse exoplanetary chemistry of atmospheres driven by flares from K-M dwarfs***

Aeroplanets: Photochemical collisional atmospheric chemistry due to XUV & Stellar Energetic Particles model

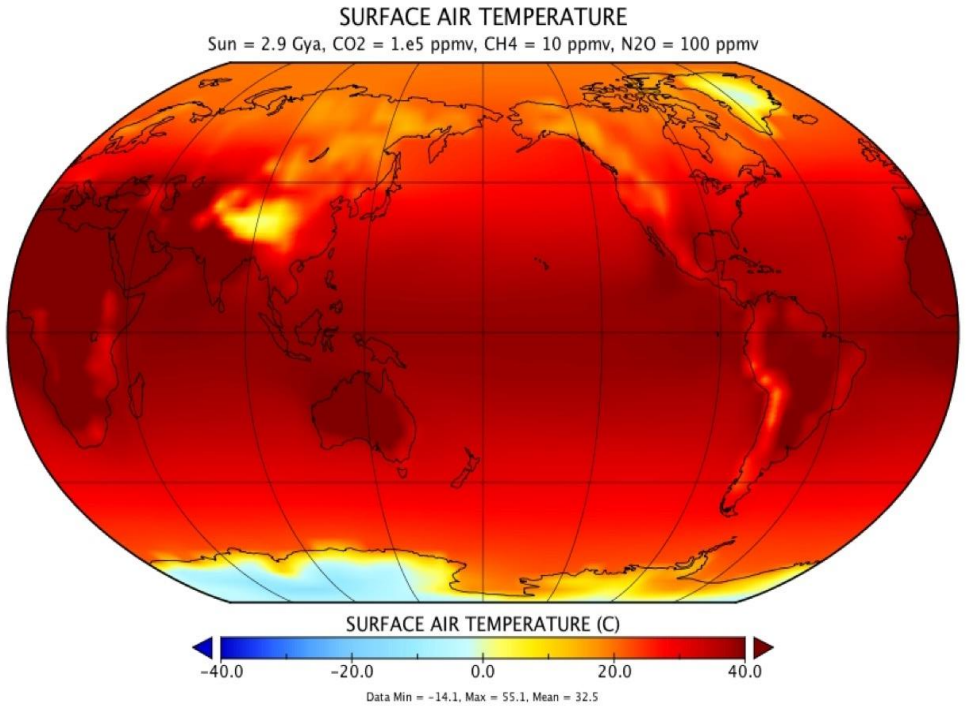






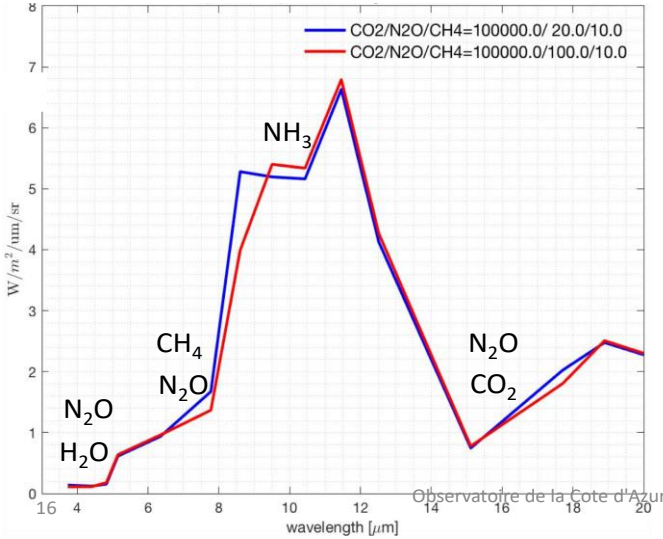
Major Results in the first 6 months of FY18

ROCKE3D model of a temperate climate of a young Earth-like planet

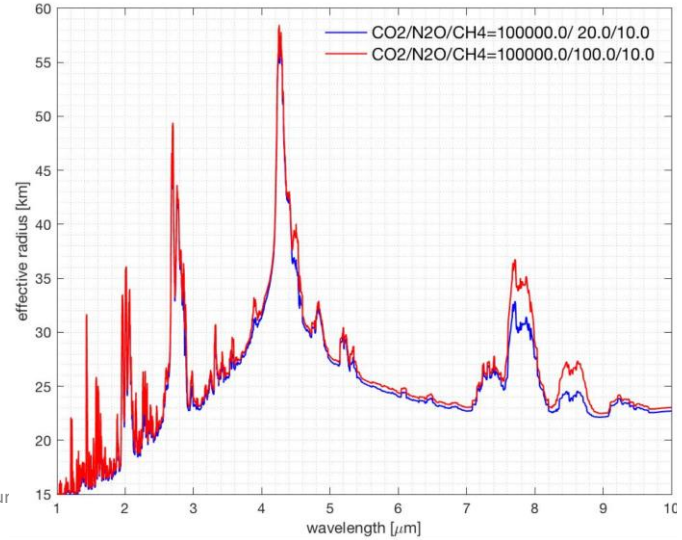


Observing young Earths

Reflectance Spectra



Transmission Spectra



Metrics Delivered

- **One paper to be submitted to Nature before the end of the calendar year**
- **Estimated number of proposals not submitted to ROSES (1)**
- **SEEC Workshop, 6 white papers**
- **New Collaborations: NExSS PI: Del Genio, W. Moore (Hampton U), G. Li (University of Alabama); Grenfell & Scheucher (Germany), Guedel (U Vienna)**

Future Work

1. Submit a paper to Nature before the end of the calendar year

2. Construct and implement SEP spectra for K-M dwarfs (FY19 & FY20)

3. Model the climates and calculate reflectance/transmission spectra of Mars to Super-Earth sized terrestrial bodies around active stars with ROCKE-3D (FY 19 & FY20)

4. XRP proposal to model CME/SEP events from active stars the first principles (seed funding from SEEC) – FY19

5. Add the core and external MHD models to EMACS (Aeroplanets and ROCKE3D, FY20)

Atmos: a 1-D Photochemical-Climate Model

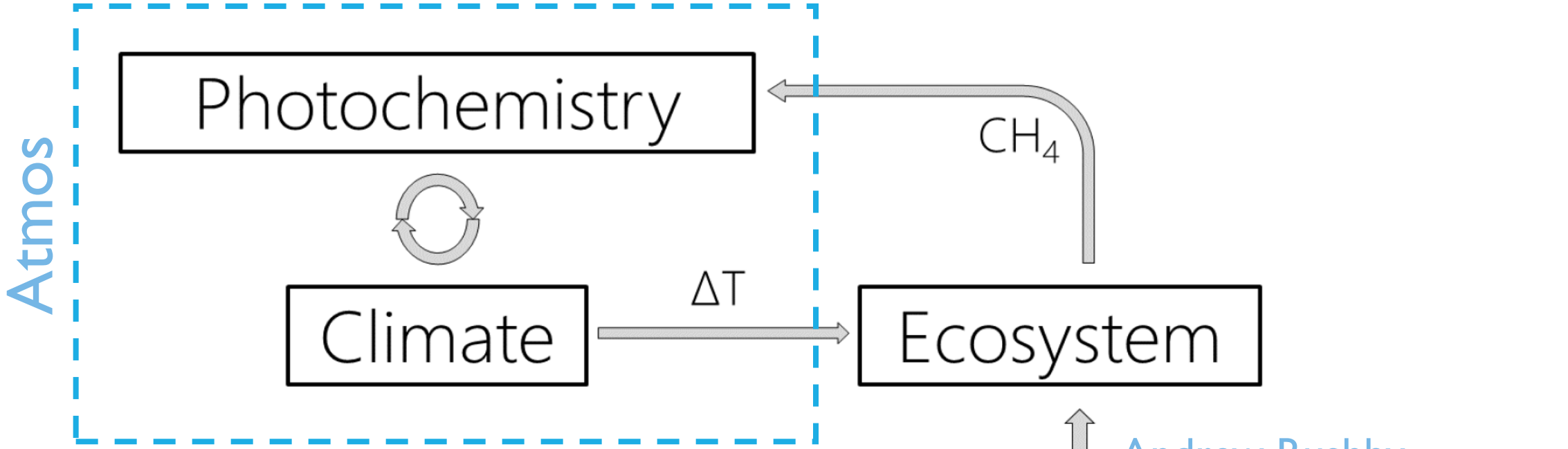
Who we are: Giada Arney, Shawn Domagal-Goldman, Ravi Kopparapu, Xandra Brosius, Mahmuda Afrin Badhan, Amber Britt (Fisk-Vanderbilt), Thomas Fauchez, Ryan Felton, Der-You Kao, Daria Pidhorodetska, Teal UMD), Alia Wofford & new collab. w/ Eliza Kempton (UMD)

- Development and improvement of a **community model** used to simulate planetary atmospheres and environments
- **Several projects**: e.g. early Earth atmospheres, new Titan template, 3-D/1-D coupling, hot Jupiters, new reaction rates, ecosystem coupling

Duration of Award: 3 years

a example of what we're working on…

Revisiting Early Earth's methanogen biosphere:



Alia Wofford

Andrew Rushby & Sanjoy Som ecosystem modeling

a example of what we're working on…

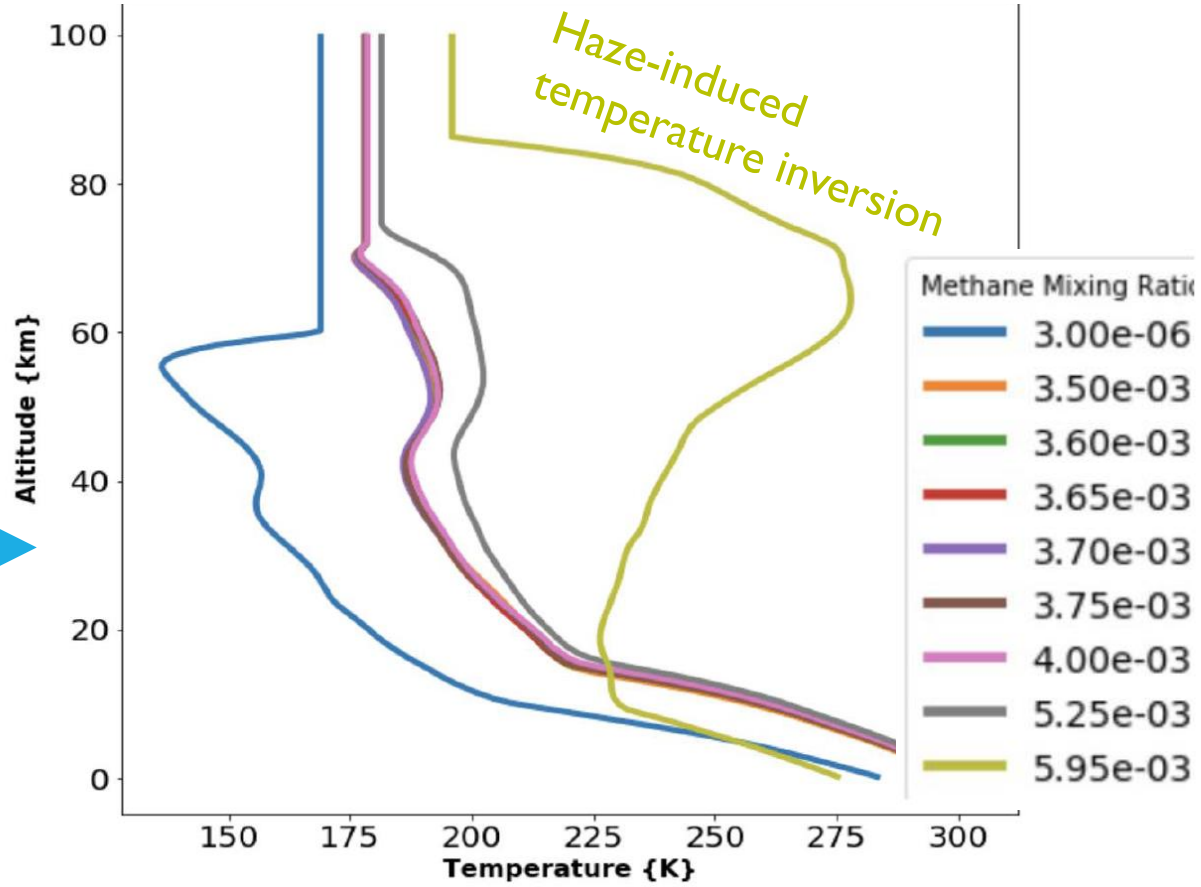
Photochemistry

Climate

ΔT

Alia Wofford

Temperature profiles – Archean Earth



what's happened & what's next?

- Presentations at AGU, CCTP-3, AAS, Goldschmidt, Habitable Worlds
- Development/improvement of an open source community model (Teal)
- New collaborations w/ Eliza Kempton (UMD), Andrew Rushby (Ames)
- Paper submitted by Mahmuda Afrin Badhan
- **Support for early career scientists/students**

Future Work, e.g.,

- Linking early methanogen biosphere project to GENIE model w/ Chris Reinhard (GA Tech)
- More model improvements: e.g. updates to reaction rates (Der-You Kao, Daria Pidhorodetska)
- Studies of diverse planets (e.g. Titan-like planets - Ryan Felton, hot Jupiters – Mahmuda Afrin Badhan)

Impact of clouds and hazes in the JWST simulated transmission spectra of TRAPPIST-1 planets in the habitable zone

Sci-PI: Thomas Fauchez

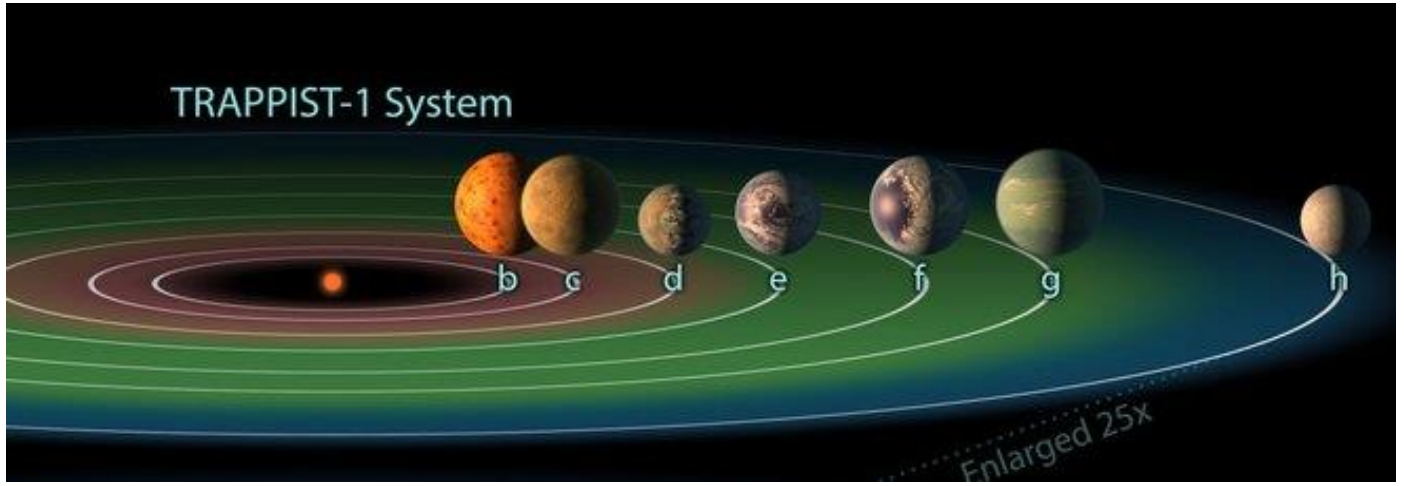
PI: Giada Arney

Team Members

Ravi Kopparapu, Avi Mandell, Michael Way, Shawn Domagal Goldman, Martin Turbet, Julien de Wit, Michael Gillon

Short Summary or main bullets

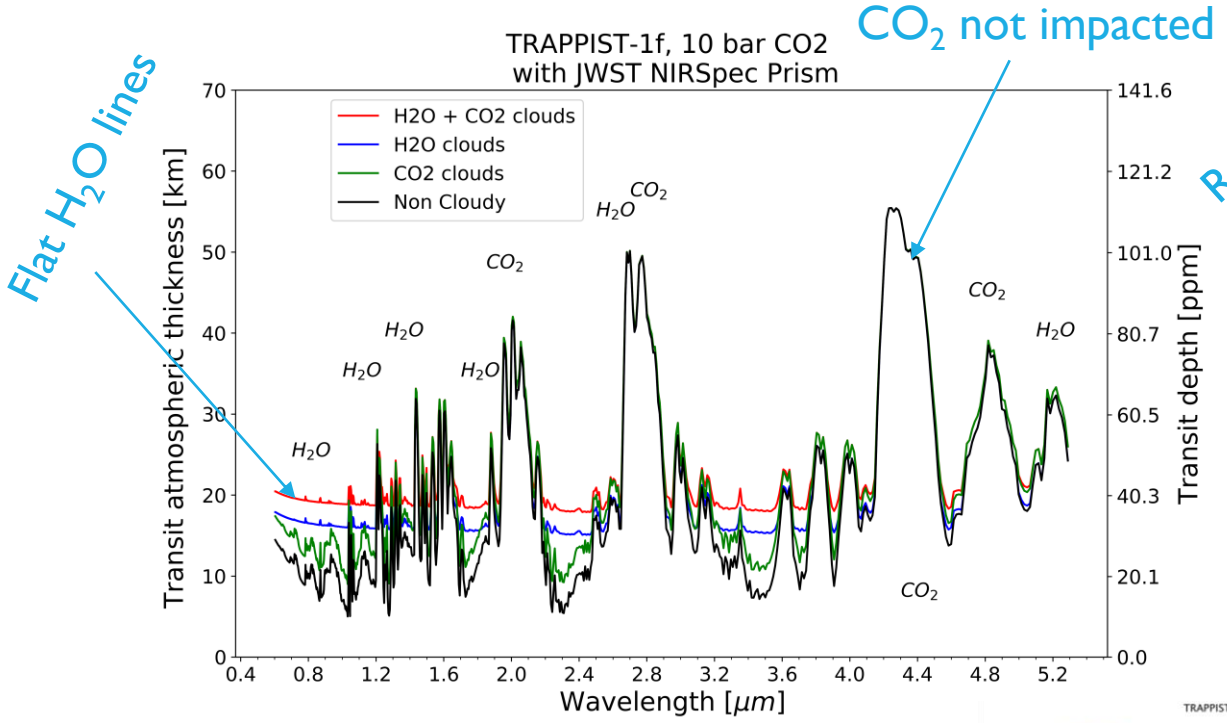
- Near the inner edge of the HZ (TRAPPIST-1e):
  - H_2O clouds strongly reduce H_2O ppm level even at low cloud fraction
  - High UV flux may produce thick hazes from CH_4 even at ~1 bar pressure
- Near the outer edge of the HZ (TRAPPIST-1f and -1g):
  - H_2O clouds strongly reduce H_2O ppm level even at low cloud fraction
  - High altitude CO_2 clouds strongly flattened the spectra
  - Lower UV flux lead to small haze opacity. Thicker haze may require unrealistic CH_4 partial pressure



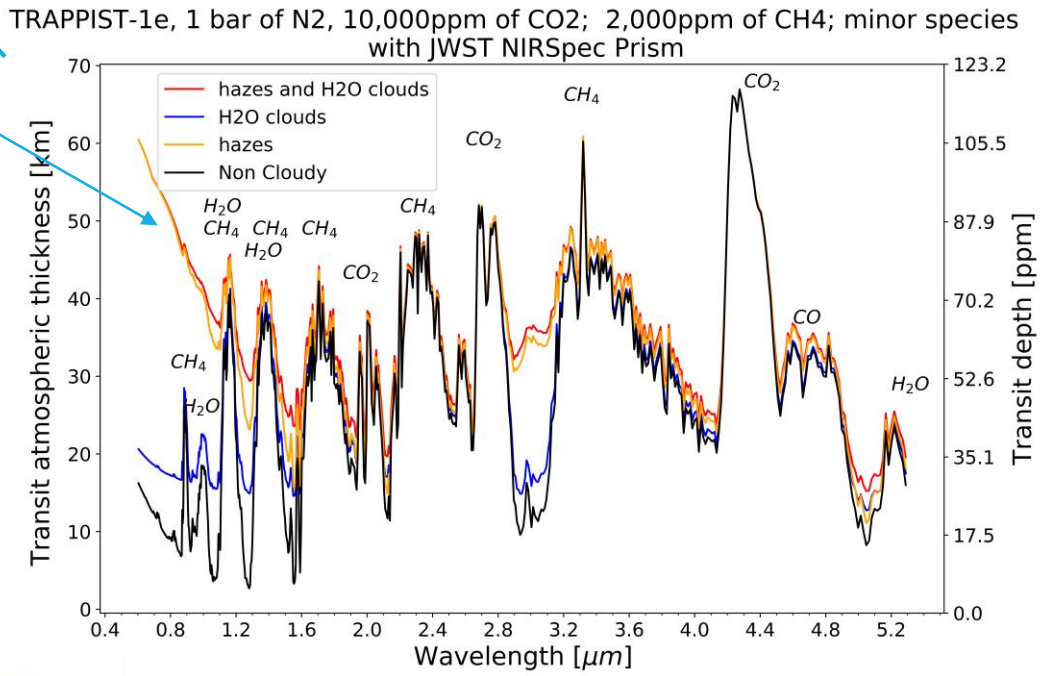
Duration of Award: 3 years

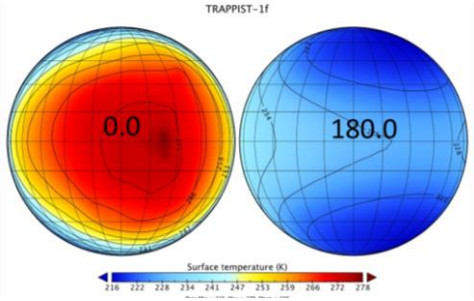
Major Findings or Results

10 bars of CO_2



Archean Earth-like





Metrics Delivered

- Summer AAS 2018 (poster) and CCTP3 (talk)
- Estimated number of proposals not submitted to ROSES:2
- New collaborations: THAI (Trappist Habitable Atmosphere Intercomparison)

Future Work, e.g.,

- Publish the THAI protocol and results
- Publish a paper on clouds/hazes
- Connections to future/ongoing projects: SEEC proposal on atmospheric variability
- Connections to mission science: deliver key message to observers about clouds/hazes on TRAPPIST-1 (like)

Photo-evaporative Atmospheric Escape Across Parameter Space

PI: Eric Lopez (693).
Collaborator: Kevin France (University of Colorado, Boulder)

Duration of Award:
FY18 (6m) – FY20

Main objectives

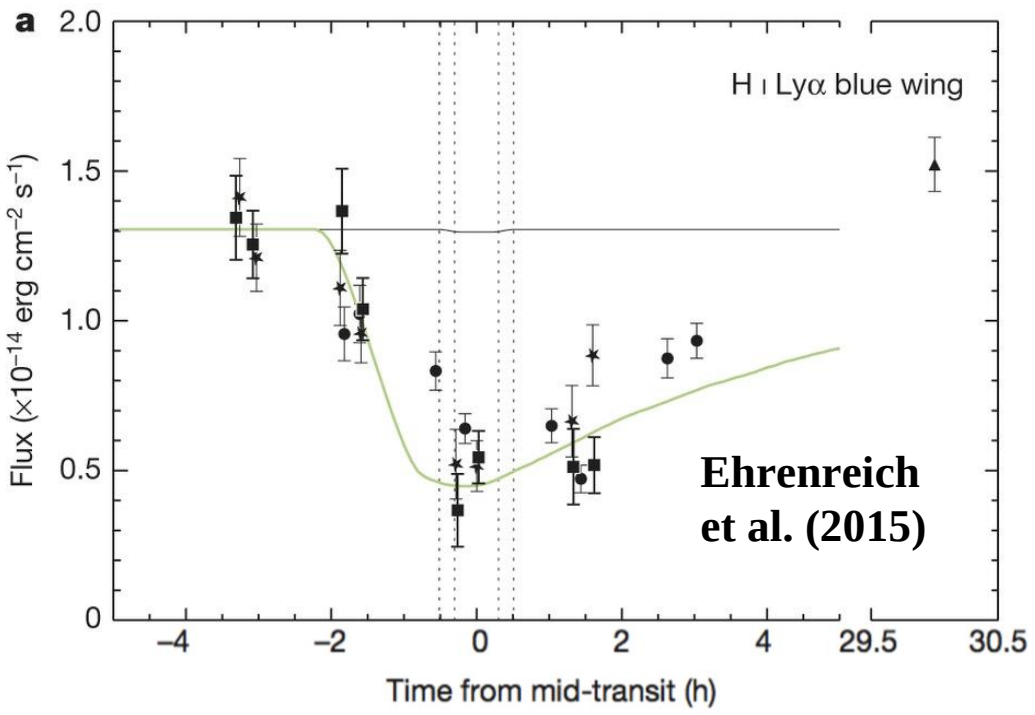
*** Develop new model of photo-evaporative atmospheric escape for highly-irradiated exoplanets using the radiative transfer code CLOUDY**

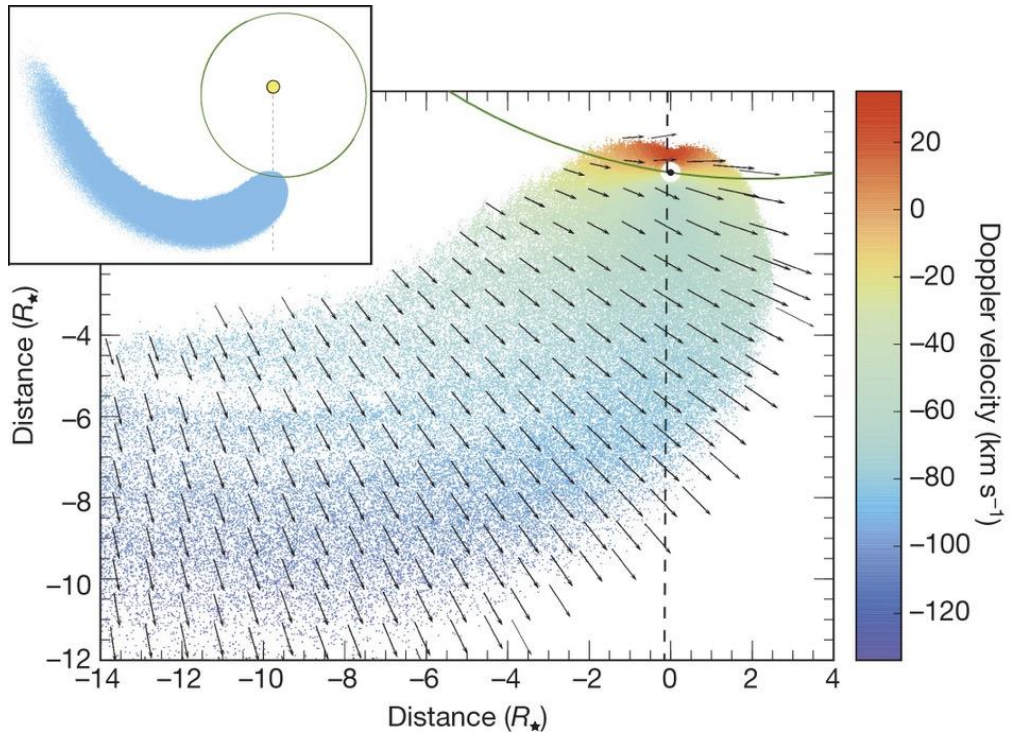
*** Predict escape rates across exoplanet parameter space, especially for metal-rich atmospheres.**

*** Provide pre-computed grids of escape rates to the community through EMAC**

*** Examine the future detectability of exospheric metals with space-based UV transmission spectroscopy**

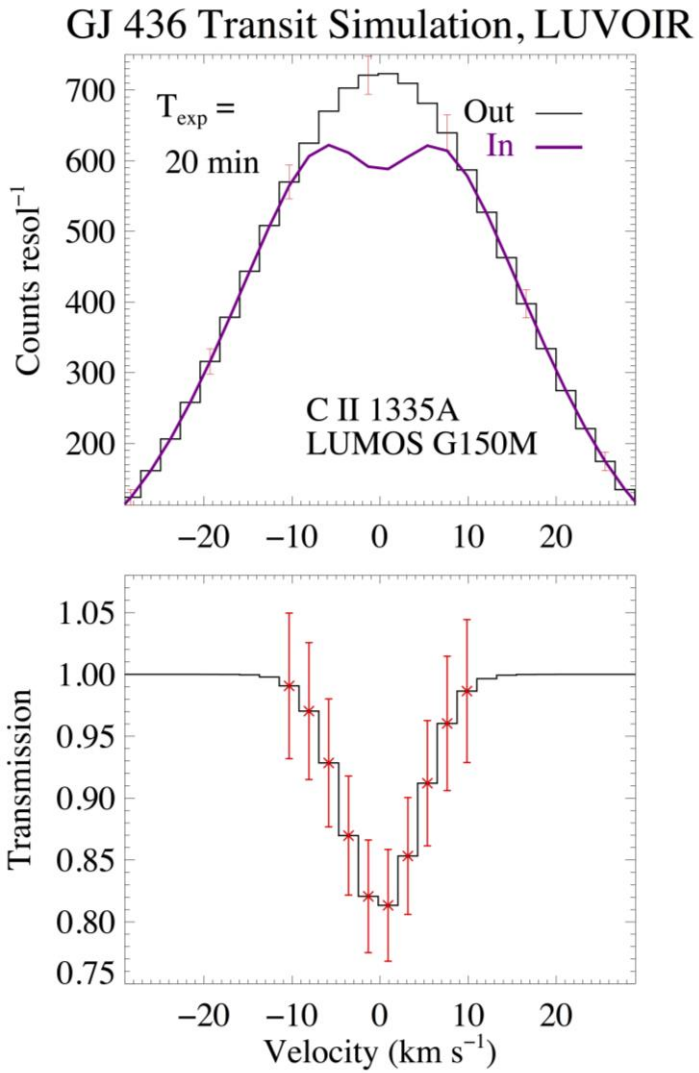
GJ 436b Exosphere Transit in Lyα from HST

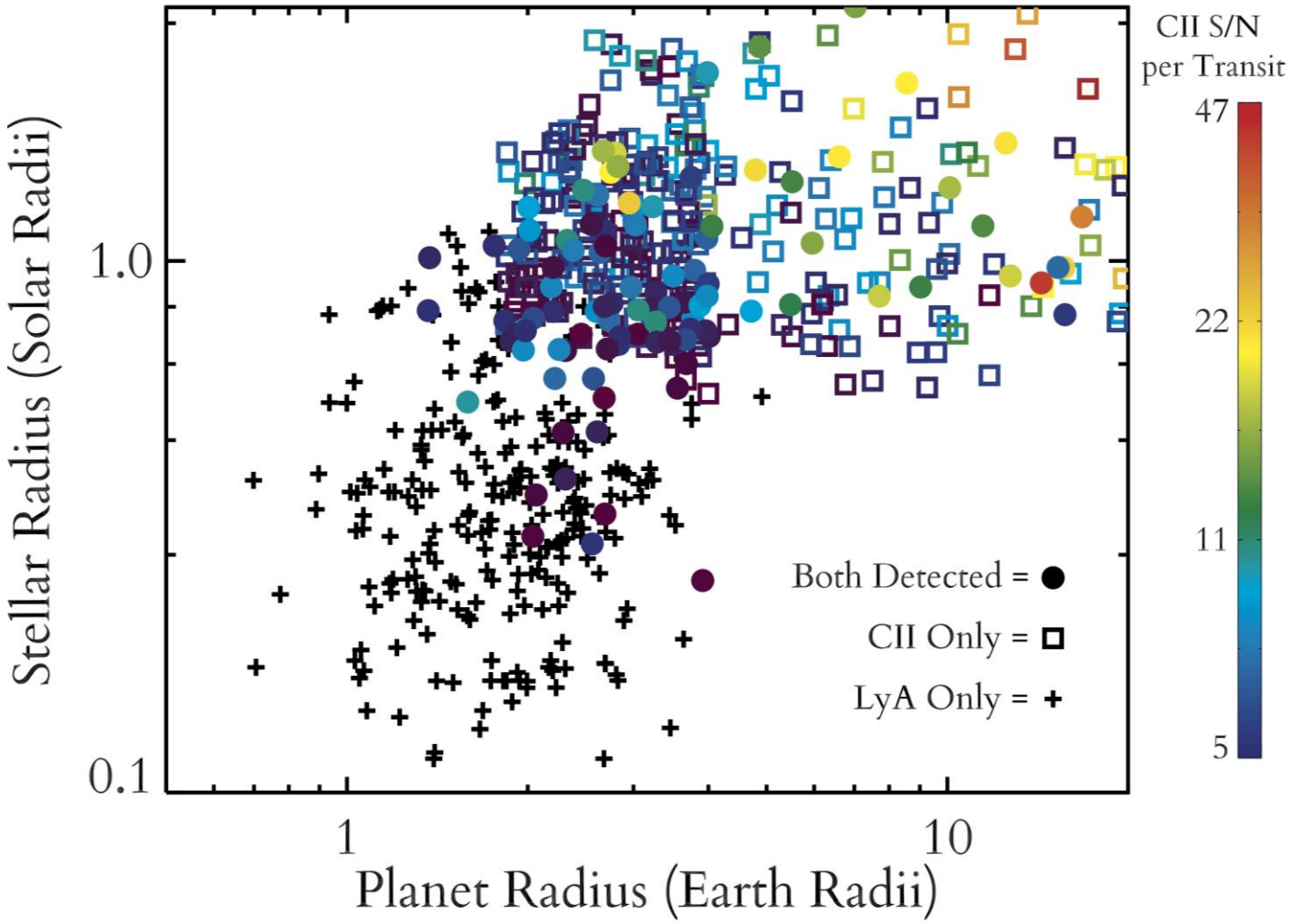




Initial Results in the first 6 months of study

- Initial results for obtained assuming Parker Wind density profile for GJ 436b, with CLOUDY used to calculate ionization balance.
- Transits then simulated in Lyα and CII at 133nm.





Metrics Delivered

- Estimated number of proposals not submitted to ROSES (1)
- New Collaborations with Kevin France (University of Colorado, Boulder) and Ruth Murray-Clay (University of California, Santa Cruz)
- Model outputs will provide key inputs for other ISFMs on atmospheric escape (including those lead by PI Airepetian and PI Lee)

Next Steps

- Further develop photo-evaporative escape models to be fully self consistent across parameter space then validate and publish.
- Provide a grid of pre-computed escape rates to other SEEC researchers working on escape and to the community via the Exoplanet Modeling Analysis Center EMAC.
- Use model outputs to examine the detectability of a wide range of atomic species in exoplanetary exospheres with UV transmission spectroscopy and make predictions for UV space telescopes including HST, HabEx, and LUVOIR.